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TECOM PROJECT NO. 7-CO-R89-EPO-004

FINAL REPORT

METHODOLOGY INVESTIGATION

OF

AI TEST OFFICER SUPPORT TOOL II

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BY

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U.S. ARMY ELECTRONIC PROVING GROUND
FORT HUACHUCA, ARIZONA 85613-7110

REPLY TO
ATTENTION OF

STEEP-ET-S (70-10r)

JAN 1990

MEMORANDUM FOR Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-TC-M, Aberdeen Proving Ground, MD 21005-5055

SUBJECT: Report, Methodology Investigation of AI Test Officer Support Tool II, TECOM Project No. 7-CO-R89-EPO-004

1. The subject methodology report is enclosed for your review and approval.

2. Point of contact is Mr. Bob Williams, Software and Interoperability Division, Electronic Proving Ground, (USAEPG), AUTOVON 821-8186.

FOR THE COMMANDER:

Brenda J. Taylor

Encl

BRENDA J. TAYLOR
Director, Electronic Technology Test Directorate

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DEPARTMENT OF THE ARMY
HEADQUARTERS, U.S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MARYLAND 21005 - 5055

REPLY TO
ATTENTION OF

6 APR 1990

AMSTE-TC-M (70-10p)

MEMORANDUM FOR Commander, U.S. Army Electronic Proving Ground,
ATTN: STEEP-ET-S, Fort Huachuca, AZ 85613-7110

SUBJECT: Report, Methodology Investigation of AI Test Officer Support Tool II, TECOM Project No. 7-CO-R89-EPO-004

1. Subject report is approved.

2. Point of contact at this headquarters is Mr. Richard V. Haire, AMSTE-TC-M, amstetcm@apg-emh4.apg.army.mil, AUTOVON 298-3677/2170.

FOR THE COMMANDER:

Grover H. Shelton

GROVER H. SHELTON
Chief, Meth Imprv Div
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This report covers the application of Artificial Intelligence Techniques to the problem of creating automated tools to assist officers; it also examines the use of an emerging AI field, neural computing, as it might be applied to this problem domain.

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FOREWORD

ACKNOWLEDGMENTS

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Mr. Nicky Sizemore, Mr. Tom Hall, and Mr. Fred Gampper developed the TPD, MET, and EVA systems, respectively, and documented the findings in this report. Mr. Hall was also responsible for the DocuView tool.

Ms. Gwen Gillen and Ms. Dawn Rumore provided skillful assistance in the technical editing of the report.

The following individuals from the USAEPG AI Office (S&I Division) developed and reported on the indicated systems:

CPT James Durham (BUD2, PT Look-up, and SEC)
1LT Andre Washington (CPEA and TTES)

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Mr. Peter Bergsneider, USAEPG (TPD)
Mr. Steve Bieda, Atmospheric Sciences Laboratory (MET)
SFC Thomas Newman, USAEPG (PT Look-up)

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SECTION 1. SUMMARY

1.1 BACKGROUND

Test design and planning for modern Command, Control, Communications and Intelligence (C^3I) systems is becoming an increasingly complex task. More sophisticated systems are requiring more complex testing, in an environment with tighter budget constraints. Modern technology imposes new demands on the tester indirectly through more complex security, safety, and environmental considerations. The result is that testing is rapidly reaching a point where the expertise required is too great for any one individual to handle effectively. By the time expertise is acquired in any one area, the individual may retire, leave, or transfer out of the organization.

The U.S. Army Electronic Proving Ground (USAEPG) has positioned itself to alleviate some of the problems faced by today's test officer, by exploiting some of the very technology which is partly responsible for this dilemma: artificial intelligence (AI) and the much improved microcomputer. Previous investigations at USAEPG, sponsored by the Department of Defense (DoD) Software Technology for Adaptable, Reliable Systems (STARS) program (reference 1), identified some aspects of AI which were sufficiently mature to insert in test tools. One of these technologies, AI expert (or knowledge-based) systems, was explored in depth.

During the earlier projects, including phase I of this investigation, prototype expert systems were developed to demonstrate capabilities and potential benefits. One of the first systems built to assess the suitability of AI technology for a proposed application is still being used to screen new proposals to eliminate those problems which are best addressed with conventional analysis methods. After the in-house skills were developed to build expert systems and differentiate between good and poor applications, a number of workshops were conducted.

The workshops produced many good ideas for expert system applications. Most applications were implemented during the workshops as "demonstration" level systems. A smaller number have evolved into more robust "prototype" versions. However, all of the systems shared the characteristics of being both developed on, and used in, a microcomputer environment. (Some of the more sophisticated applications built on other funded projects at the USAEPG have been more suitable to implementation on specialized AI machines.) The viability and cost effectiveness of these microcomputer-based expert systems was shown during phase I of the investigation (reference 2). USAEPG continued to exploit this successful AI application methodology during phase II, whose efforts are documented below.

1.2 OBJECTIVE

The objective of this investigation was to provide the test officer with automated support tools by inserting AI technology in appropriate applications. Objectives for the development of these tools included:

a. Orientation toward the test officer as primary user.

b. Wide usability to satisfy the needs of the approximately 100 test officers at the USAEPG.

c. Ready availability (microcomputer based).

d. Reduction in time to perform a given task and/or improved quality of the result.

e. Education of the user (test officer) in addition to merely providing a solution.

Finally, as testers, another objective was to continue to identify test methodologies for the test and assessment of systems containing AI.

1.3 SUMMARY OF PROCEDURES

Lessons learned from earlier work on expert system development were applied to restructure the original proposed approach. Rather than develop a single test officer tool on the one available AI machine, an approach more in consonance with the objectives was established. This approach called for the development of a number of small tools, rather than risk all of the available resources on the success or failure of a single large tool. The development of smaller tools hosted on microcomputers also provided a more flexible means of adjusting to resource constraints, while still benefiting from the technology.

This modified approach provided prototype versions of the Test Plan Drafter (TPD) and Environmental Impact Assessment (EVA) systems. From this initial base, new ideas were developed in the areas of meteorological support, budget, security, contract monitoring, and supporting tools. Systems addressing these problem domains were developed using the workshop methodology: problem domain experts and knowledge engineers were paired to develop AI-based test officer support tools.

Finally, the issue of testing AI systems was investigated further; first, because the development of expert system-based tools require an in-house test philosophy; and second, because test items employing AI technology are likely to appear in the near future.

1.4 SUMMARY OF RESULTS

A number of AI expert systems were developed to aid the test officer in performing duties associated with testing. With respect to the application objectives outlined above, these systems satisfied those objectives as follows.

a. The knowledge domains of the expert systems centered on areas of expertise of which an experienced test officer would be cognizant, but not necessarily an expert. In other words, a test officer might be familiar with certain security or contract monitoring requirements, but would still require considerable consultation with a domain expert to satisfy the requirements for a new test. The systems built during this phase of the investigation were intended to assist test officers by providing the preliminary advice normally obtained from the domain expert during test planning.

b. Most of the systems developed are still in the evaluation phase and therefore have been installed on a limited number of computer systems. A future consid ration when these systems emerge from the prototype stage will be to examine the use of a central host computer for distribution and configuration management purposes.

c. All of the systems were targeted for the microcomputers available at USAEPG. Because of the different configurations in use, some constraints exist as to which functions can be used while still retaining compatibility with a majority of the microcomputer base. Primarily these constraints have concerned disk and memory size, graphics capabilities, and hardware accelerators for floating point operations. From a practical standpoint, little functionality has been lost in conforming to the minimal configuration.

d. An assessment of time savings or improved quality, due to the use of expert system aids, can only be done qualitatively, since all of the systems are just now being evaluated using actual test project parameters. Projected savings are considerable in some cases; in one evaluation run, the EVA assisted in identifying excessive and unnecessary test requirements. Other expert systems offer the potential of providing preliminary assistance in what can be complex or time consuming tasks. All of the systems have demonstrated the ability to retain, and even combine, expertise from human domain experts.

e. The present suite of support tools all serve to train the test officer to some degree. After running the expert systems a few times, the user begins to understand which parameters are significant for given situations. Also, all of the systems provide an on-line "help" function to inform the user of the nature of, and appropriate response to, the various queries encountered. Most of the advice offered by the systems provides both the necessary action and the reason for the action; e.g., use of incendiary devices requires filing a fire plan with the post fire marshal.

f. Test technology for AI expert systems is almost nonexistent. However, some progress has been made in isolated areas, but much remains to be done before AI test methodologies can be considered mature.

1.5 <u>ANALYSIS</u>

The development of various expert systems to aid the test officer demonstrates the usefulness of AI technology. The systems are still being evaluated, and will probably continue to evolve to support more of the domain knowledge. Besides the obvious benefits, such as retained knowledge and combined expertise of multiple experts, this methodology showed the feasibility of developing and using expert system technology with existing microcomputer resources. In addition, improved productivity and quality of work can be expected from test officers. With fewer resources available to perform essential mission functions, productivity and quality gains may overshadow other potential advantages of AI.

The systems developed for the investigation addressed individual problem domains within the testing arena. Many of these domains share commonality of information about test resources, techniques, and requirements - the infrastructure of testing. A broader analysis of this test support infrastructure requirements is appropriate. An early examination of the testing infrastructure, with subsequent incorporation of common requirements into a supporting structure (i.e., data bases, networks, geographic information systems, and standard information elements), could eventually lead to an integrated set of cooperating support tools.

AI appears in two complementary areas at the USAEPG: embedded in test items (usually, Army systems) which must undergo developmental testing, and used in test support systems. The introduction of AI into test items makes it imperative that a test methodology be developed so USAEPG may perform its primary mission of testing. Almost equally important is the need to be able to validate test support tools which use AI. Until robust AI test methods emerge, the full potential of this promising technology will not be realized.

1.6 CONCLUSIONS

The investigation was successful in demonstrating the capability of knowledge-based systems. This was accomplished with existing microcomputer resources, which increased the availability of the tools while minimizing costs. Further validation of this microcomputer-based expert system development methodology over a complete system life cycle would require that the prototype tools complete the ongoing evaluation phase. Following a favorable evaluation, the tools would then be fully developed and supported under production or instrumentation programs, for the remaining implementation and maintenance portions of the life cycle.

Automating the entire test infrastructure is too ambitious an effort to be absorbed by follow-on phases of this investigation. However, some consideration should be given to defining the infrastructure requirements for the production version of knowledge-based systems.

Since test items are already being developed which employ expert system technology, and knowledge-based test support systems have been shown to be beneficial, more emphasis should be placed upon initiating an AI test methodology investigation.

1.7 RECOMMENDATIONS

Further investigation is recommended in the following areas:

a. Use of the prototype tools should continue through the evaluation phase to attempt to further validate the results obtained thus far. Distribution and operational considerations associated with the implementation phase of a system should be addressed, as well as maintenance issues. Further development of test officer support tools should also incorporate infrastructure requirements to the extent possible.

b. A separate project should be undertaken to analyze the requirements for establishing and maintaining an automated testing infrastructure.

c. An investigation is required to develop test procedures for AI. This effort would aid directly in accomplishing the primary mission of system testing, and would also offer a means to validate AI-based test support tools.

d. Advances in AI technology should be monitored to maintain cognizance of new developments in this rapidly maturing field. This should include those aspects of AI which have been explored only briefly during this investigation.

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SECTION 2. DETAILS OF INVESTIGATION

2.1 APPLICATION OF AI

USAEPG is one of nine test centers of the U.S. Army's Test and Evaluation Command (TECOM). TECOM has established two goals for the use of AI technology, which are also the primary goals of USAEPG's AI effort. One goal is to exploit AI technologies to enhance the ability to perform testing. The other, somewhat obvious goal, is to test systems which contain AI. Another ancillary role which AI plays is to improve upon existing methods by examining existing processes, listening to experts/users, and in general defining and improving the job to be done.

USAEPG, like the other subordinate elements of TECOM, assigns action officers to oversee the activities associated with test directives. These test officers perform a number of duties. Besides test planning, the test officer is responsible for monitoring actual test conduct, and analyzing and reporting the results. With test items increasing in complexity due to the increased use of electronics, computers, and communications, the test officer's responsibilities are similarly becoming more difficult. This would be sufficiently challenging without the additional burden of reduced budgets and increased documentation requirements. At USAEPG alone, approximately 100 personnel are designated as test officers, with responsibility for conforming to all of the appropriate directives, regulations, and guidelines without losing sight of the primary mission.

The current phase II of the investigation continued earlier efforts to examine the potential of applying microcomputer-based AI technology to assist the test officer (reference 2). Increased emphasis was placed on managing the technology rather than merely building tools. This approach required that all aspects of an AI development infrastructure be addressed. Some of the essential ingredients of this methodology were the team organization, training for personnel at all levels in the organization (including an apprenticeship program), and the development of various AI-based support tools and exploration of AI testing issues.

2.1.1 AI Background.

AI encompasses a large and somewhat diverse set of technologies, ranging from neural computing to robotics, and including expert systems, natural language processing, and vision systems. One of the more mature technologies of AI is that of expert, or knowledge-based, systems. AI developers have produced tools known as expert system shells that assist in the construction of rule-based expert systems. These shells allow a knowledge engineer to codify logical inferences (rules) about a given domain, and to process the resulting knowledge base in order to provide expertise to the user.

Most non-trivial expert systems have been developed by a team consisting of AI experts and domain experts. It is the job of the knowledge engineer to obtain knowledge about a particular domain through consultation with one or more experts, documented information, or some combination of these sources. This knowledge is then incorporated into an automated tool which uses this expertise in solving problems within the domain. Expert system shells have considerably eased the task of developing expert system tools, by providing a means to enter and exercise logical rules about a given domain.

Recent developments in expert system shells have resulted in a number of tools which are relatively easy to use, and do not require extensive programming skills such as those normally associated with using symbolic programming languages. These shells have made it possible for some domain experts to build expert systems without assistance. However, knowledge engineering encompasses more than merely entering rules in the proper format.

2.1.2 Application Screening.

Applications proposed for test officer support tools were screened by an existing tool which assesses the probable success of a proposed system by analyzing various parameters of the project. This system, the Expert System Selector (ES^2), is itself an expert system. ES^2 examines such factors as the availability of expertise and supporting development and runtime tools; and the suitability and feasibility of an expert system solution. It then provides a qualitative score of the overall success potential. Proposed concepts had to be sufficiently well defined to allow grading by the ES^2. Only then could those concepts be considered for development. This approach, in fact, was used to screen ideas for the workshops, and was responsible for the elimination of what would have been poorly suited or overly ambitious suggestions.

2.1.3 Microcomputer Development Environment.

The computing resources of USAEPG include a variety of mainframe, mini, micro, and special-purpose AI computers. However, only the ubiquitous microcomputer is readily available to the test officer for planning functions. Earlier AI efforts demonstrated the practicality of AI systems targeted for these machines, although microcomputer implementations are not without their own unique challenges. One problem centers on the need for practical methods to handle distribution and configuration management. Another problem, not strictly limited to applications on the small machines, is the need for production level systems to access information and knowledge on the testing infrastructure.

Automation of the testing infrastructure within the context of a large organization requires at least two types of knowledge. The first type, knowledge of the domain in which the system is to advise and assist, is termed domain expertise, and is the object of the knowledge acquisition effort as commonly described in AI literature. The second type involves information concerning the administrative, organizational, and regulatory environment within which the expert and system must operate. Within USAEPG, as with most organizations, requisite information is widely available, but from a variety of sources. At this time, there is no central point for maintenance of or access to this infrastructure information.

2.1.4 Team Structure.

USAEPG AI efforts are managed out of an office in the Software and Interoperability Division. The team consists of management, engineer, and apprenticeship personnel, supplemented with personnel from an existing technical support contract. Upper management also plays a key role in obtaining the commitment and resources so essential to the insertion of new technology. Because a successful technology development program requires both adequate tools and the management and technical skills to effectively use the technology, a considerable amount of emphasis is placed on training at all levels in the organization.

2.1.5 Management Involvement.

Management participation is an essential element of any new technology insertion effort. The approach followed during this investigation included aspects of training as well as oversight activities. Management training was obtained through special courses and by participation in workshop activities. The Management of Expert Systems Course, presented on site by the U.S. Army Signal Center and School, was attended by 15 USAEPG and 7 TECOM management personnel. Another 7 personnel from other organizations at Fort Huachuca also attended. The course covered all aspects of expert systems from planning to actual design-on-paper of a class exercise. This coupled with active participation in AI development efforts gave management the insight to properly incorporate this new technology.

Management oversight was cultivated through the establishment of a steering committee. The goals of the committee meetings are to provide the communication channel to senior management from the AI cell and provide a forum for resource commitments and priorities to be assigned to proposed projects, based on command perspectives.

2.1.6 Apprenticeship Program.

An apprenticeship program is used to train new members of the AI team, as well as personnel outside the division. For team members, the apprenticeship represents part of the initial training which is received. For others, the apprenticeship is a way to develop projects quickly.

An apprentice begins by being temporarily assigned full time to the AI Office, minimizing the interruptions which would occur if he or she were to remain in their regular assignment. Although the actual period of training varies with individual ability and desired accomplishments, the average time allowed is four months. At the end of this period the apprentice will be familiar with the basics of developing rule-based expert systems with the use of shell tools. Also, the trainee will have developed at least one prototype application to satisfy some need at their home office.

The apprenticeship begins by attending a two week course in basic expert system building and participating in local workshops. While this training is generally available to most personnel, the apprenticeship offers a number of advantages. Most people who attend long courses on their own return immediately to their home office and spend their time trying to catch up on work they missed. By the time they get around to applying the techniques they learned in the AI course, much of the effectiveness of the training will have been lost. In the apprenticeship program, students are able to learn new concepts and tools and immediately begin to apply this knowledge. Not only does this greatly improve the education process, but it allows more advanced techniques to be assimilated within a shorter time. Augmenting the basic training by exposure and actual experience with concepts merely touched upon in the basic courses allows the apprentice to build better systems more effectively when they return to their home office.

While the apprentice and his or her home office serve to benefit directly from the program, the AI office is also compensated. One of the goals of the AI office is to educate as many personnel as possible on the benefits and capabilities of AI. Apprentices help achieve this goal by serving as tutors of AI to members of their home office. Also, while an apprentice, a person will usually be assigned to participate in the development of an expert system or expert system tools which support current efforts of the AI team. The synergism provided by this program makes this a good approach for leveraging the limited resources of an organization.

2.1.7 <u>In-house Workshops</u>.

In-house workshops provided much of the training on specific rule-based tools. (Additional tool training was obtained from the U.S. Army Signal Center and School for the M.1 shell.) Attendees included USAEPG AI team members, AI developers from other activities, and, in some instances, test experts. The objective of the workshops was to familiarize personnel with the technology and to solicit ideas for further development. Workshops consisted of approximately ten students (or student/expert teams), each of whom built a small expert system as a class exercise. Of these, some ideas were selected for development of a prototype system, based on a management review of the class projects. One side benefit was the exposure of both management and test experts to the capabilities and limitations of expert systems.

In addition to training in rule-based shells, the workshops have provided a forum for exposure to other aspects of the technology. Other areas touched upon have been neural networks, hypertext, and example-based shells.

2.1.8 <u>TECOM Involvement</u>.

TECOM, parent command of USAEPG and other test centers, has supported AI technology insertion efforts in a number of ways. USAEPG has been designated as the support center for AI within the command, providing planning functions and training such as the workshops. Workshops are often held in conjunction with AI planning meetings, so that AI contacts from the other test centers can participate in both functions. TECOM has also designated the chief of the USAEPG AI Office to act as technical agent for AI matters within TECOM, and to represent the other test centers. This considerable commitment on the part of TECOM to share resources has helped leverage the limited assets of the individual test centers.

2.2 AI APPLICATION DEVELOPMENT

An AI expert system development methodology was synthesized from the lessons learned from previous projects, AI technology capabilities, computer resource availability, elements of the testing infrastructure. This resulted in an approach similar to that used by industry for smaller AI applications:

a. Acquisition of microcomputer development tools and development of related personnel skills.

b. Identification of suitable applications.

c. Teaming of a knowledge engineer and domain expert(s).

d. Prototyping and iterative development of the expert systems.

The result of implementing this methodology was the generation of a number of small expert systems which address problems encountered by the test officer. Most of the systems deal with requirements during the planning phases of a test. This is not an indication that expert systems are not suitable for test conduct or reporting activities, but probably does reflect the greater stability and better defined nature of the planning stage. That is, test plans and environmental documentation are always required, regardless of other variations in the test conduct activity. Another drawback to addressing test conduct requirements is that these applications are relatively large, and would consume all of the available resources for a single system.

2.2.1 New Expert Systems.

The prototype test officer support tools built during the investigation are described below. For each system, the purpose and goals, domain, requirements, description, design characteristics, benefits, and status are briefly described.

2.2.1.1 Contract Performance Evaluation - Advisor.

2.2.1.1.1 Purpose/Goals. The Contract Performance Evaluation - Advisor (CPEA) has been developed to assist test officers in evaluating a contractor's performance of work. The goal of CPEA is to ensure that uniform standards are applied to performance evaluations for all of the tasking on large contracts.

2.2.1.1.2 Domain/Expertise. Knowledge used in the CPEA system was acquired from experienced test officers and contract support documentation such as standard operating procedures (SOPs). Test officers also played a major role in the systems design, which was developed by personnel in the apprenticeship program. (However, prior to the apprenticeship the developer had served in the division in a capacity that required him to perform contract evaluations.)

2.2.1.1.3 Requirements. The requirement for a contract evaluation expert system came about as a result of the need to standardize the process in which scoring is done. Also, when management selected the CPEA as a workshop system to be developed into prototype form, they were interested in speeding up the process. Other requirements included automating the evaluation process, generating reports, designing the program so users would be forced to address each evaluation subfactor, and addressing situations where the answer to a particular question in unknown. Another desired feature was to allow the test officer control over the final score received by a sub-factor; the test officer is given a five point range of scores and is allowed to make the final decision on a score taken from within the range.

2.2.1.1.4 Description. CPEA asks the user specific, low level questions for which they are likely to know the answers. Based on the responses, a recommended range of scores are offered to the test officer for each subfactor in the evaluation. After all of the questions (56 in number) are answered, CPEA prints out a report, and saves the information on disk storage. There is also an option available for printing reports that depict the answer to each question.

2.2.1.1.5 Design/Development Characteristics.

The system was developed on an MS-DOS compatible microcomputer. A rule-based expert system shell, M.1, by Teknowledge, was used to provide the inferencing environment in which the CPEA knowledge base is run.

The system inferencing is done using backwards chaining. There are three levels of inferencing that work with 71 rules. Conclusions/recommendations are made using weighted scores and fact tables that relate responses to questions. Combined responses for a subfactor result in a five point recommended range. The test officer can then select the number within the range which is most appropriate.

2.2.1.1.6 Validation/Test Methodology. CPEA was tested by manually scoring the same sub-factors as used in the CPEA rules and fact tables. The output of this method was then evaluated to insure that answers were the same as those produced by the automated expert. The program is still in the process of being validated. Validation also is being performed by comparing a test officer's scores generated manually with scores generated using CPEA.

2.2.1.1.7 Benefit/Use. CPEA has accomplished the goal of standardizing scoring procedures. However, it is not likely to save time relative to manual methods, nor to result in significant changes to the contractor's award fee.

2.2.1.1.8 Development Status.

The system is in its second phase of development. This phase included upgrades in the area of default scores, and special reports to be used by management to review a test officers evaluation.

Future development will consist of interfacing CPEA to a local area network that will then interface with Lotus 1-2-3 and dBASE files.

2.2.1.2 Security System.

2.2.1.2.1 Purpose/Goals. The Security Expert System (SEC) was built with one underlying theme, enforcement of the security SOPs of the USAEPG. The main goal of the system was a combination of the following ideas: 1) Make all test officers aware of security needs for a test. 2) Give the test officer a list of security do's and don'ts. 3) Help the Intelligence & Security Division do security risk analyses of the testing programs at USAEPG.

2.2.1.2.2 Domain/Expertise. Expertise for the development of SEC came from the automated data processing (ADP) security manager, the information security specialist of Intelligence & Security Division, Army Regulation 380-5, and DA Pamphlet 190-51.

2.2.1.2.3 Requirements. The SEC is required to determine if a test project needs any hard products (e.g., guards, safes, or courier orders) or advice (for example, procedures to be followed) that Intelligence & Security Division can provide. The system also must aid the user in doing a security risk analysis of the test site and project. Once completed, the risk analysis will identify a set of security procedures and protective measures that the test officer is responsible for.

2.2.1.2.4 Description. The SEC consists of three main modules, covering the areas of information security and physical security. As each module is completed the responses the user gave are stored in ASCII files for later review and print out. The first module collects the background information on the test project (e.g., project title, TECOM project number, the test officer's name and testing dates). Next, this module covers information security issues and procedures, indicating how to secure hard information. Another module then does a risk analysis to identify the security procedures and protective measures that the test officer must be aware of as they apply to aircraft, vehicles, and electronic equipment. The last module collects all the saved responses and prints out a report for the Intelligence & Security Division files.

2.2.1.2.5 Design/Development Characteristics. SEC is a microcomputer-based expert system written using the M.1 shell and a text editor. The expert system was divided into several procedural modules. These modules were designed to be individually called into memory and run. Then information learned is saved to separate files. The system was built in pieces, individual modules being set up to handle small requirements of the security problem (e.g., conducting a risk analysis, or determining if guards are required at a test site).

2.2.1.2.6 Validation/Test Methodology. As the system was developed and modules added, a security specialist from Intelligence & Security Division ran the system to evaluate the latest changes. A small group of test officers acted as a beta test group to further evaluate and improve the system.

2.2.1.2.7 Benefits/Use. SEC was designed for use by test officers as an aid for security matters as they pertain to a test project. It will be their first and most readily available source of security guidance. There is no requirement at the USAEPG for test officers to develop a security plan for their test, but they are responsible for the security of the test site, equipment, and data. This expert system will help them fulfill this responsibility.

2.2.1.2.8 Development Status. The prototype SEC is ready for distribution and use throughout USAEPG. Presently, no user manual or documentation exists, yet these are not needed to load or run the system on a microcomputer.

Intelligence & Security Division plans to introduce the system to all of USAEPG and via a command directive require its use for all test programs in the future. Training will be accomplished through formal classes, with student comments used to formulate requirements for future enhancements.

2.2.2 Previous Applications.

Previous phases of the investigation resulted in the development of a number of applications. Those systems described in earlier reports are included in Appendix D. Currently these systems are in an evaluation phase or are in the process of entering a production version phase under other funding programs.

One of the benefits of AI systems is their use to retain expertise. Since the development of these earlier prototypes, the value of this benefit has been validated by the personnel changeover of experts for two of the applications. Another benefit is cost savings over existing methods. While difficult to quantify, especially for systems in the prototype stage, some savings have already been realized. During one use of the EVA environmental screening system, an anticipated need for fifty support vehicles was reduced to the real requirement of three vehicles. This reduction to appropriate levels resulted in direct cost savings and a test which was more benign to the environment.

2.2.3 Other Applications.

The systems described in this section were written to explore potential uses and capabilities of AI, and as part of the apprenticeship training exercises. Being exploratory in nature, these ideas were not subject to the ES^2 screening process used on other applications. These applications required approximately four manweeks each to develop into a demonstration form. One of the objectives was to examine the use of expert system shells to satisfy conventional application requirements (for example, shells provide a built in capability for queries and report generation).

2.2.3.1 Budget Spreadsheet Analysis Aid.

2.2.3.1.1 Description. BUD2, Budget Spreadsheet Analysis Aid, is a small rule-based expert system written largely in Lotus 1-2-3 macros and the expert system shell, EXSYS. It was designed to help the Directorate Chief by giving him a quick analysis of a budgetary spreadsheet. The system does a quick scan of the monthly Obligation and Disbursement spreadsheet used here at USAEPG. This Lotus spreadsheet contains a list of test projects or project funds, indicating a past history and current levels of disbursed and obligated funds. BUD2 reads the output from Lotus and flags projects that are off track with the planned obligation and disbursement levels for that project.

2.2.3.1.2 Lessons Learned.

Lotus macros can be a powerful programming language. Because of BUD2's size and simplicity, all the rules written in the EXSYS shell could have been done entirely in Lotus macro code. Executing solely in Lotus would reduce the operating time for the user.

Within USAEPG, the users of application software, like Lotus 1-2-3, have their own set-up or configuration for that software. BUD2 was designed to run the Lotus software package on the user's machine. To get around differences in the set-up, BUD2 must first reset several parameters to the same values used on the developer's computer.

2.2.3.2 Tape Test Expert System.

2.2.3.2.1 Description. The Tape Test Expert System (TTES), developed with M.1, is designed to assist small Army units in the administrative task of determining a soldier's body fat percentage. The system is used when soldiers fail to meet Army screening weight requirements as identified in AR 600-9. TTES requests measurements taken from certain areas of the body. That data is then utilized to look up corresponding figures and to perform some elementary math. The results produced by TTES shows a soldier's body fat percentage and tells whether or not the soldier meets the Army's requirements. TTES is not an expert system. It is simply an automated way of performing this particular function quicker and more efficiently.

2.2.3.2.2 Lessons Learned. TTES has provided users a more consistent method of performing body fat analysis procedures and calculations. TTES also reduces the amount of stress on the soldiers being examined, by providing results within thirty seconds after data is collected. TTES is currently being used consistently by one USAEPG company. Due to the fact that there are several programs available that can perform this function, no future development is planned.

2.2.3.3 PT Look-up.

2.2.3.3.1 Description. Physical Training (PT) Look-up is a prototype system for a microcomputer, written using the expert system shell M.1, and Sidekick as the text editor. The knowledge used in this system came from the Army Physical Fitness Test scoring card, DA Form 705 PT. It was developed at the request of operations personnel. PT Look-up is a knowledge-based program, intended to help the records clerk in the company training office fill out a DA 705 scoring card after a soldier has taken the Army Physical Fitness Test. The clerk first enters the soldier's name, age, and sex. PT Look-up then asks for the number of repetitions of push-ups and sit-ups the soldier completed. If the numbers are valid, the expert system returns the point value corresponding to that number of repetitions. The user then records these numbers on the score card. The system then asks for the time it took the soldier to complete the two-mile run. Once that information is entered, the system returns the corresponding point value for that time and the sum of the three point values for a total PT test score. The last two numbers are then recorded and the card is complete without the clerk having to search the scoring tables for a point value, add the values, and double check the point values taken from the table.

2.2.3.3.2 Lessons Learned.

This system exemplifies the use of an AI shell in the programming language role. PT Look-up doesn't contain any rules from an expert, but rather is a lot of simple procedures linked together to act like someone who is filling out a DA 705 PT. The procedures are actually in the body of if-then rules.

PT Look-up has turned out to be one of the most regularly used systems in USAEPG, for the following reasons:

a. The intended user defined the product and stated the requirements.

b. PT Look-up saves the user time in doing a tedious job.

c. The records clerk has the obligation, by command directive, to keep track of DA 705 cards for every soldier in the unit.

2.2.4 Workshop Systems.

2.2.4.1 Workshop Overview. One of the goals of the USAEPG AI Office is to educate both users and management on the capabilities of AI technology. One method of achieving this goal has been to conduct periodic workshops. In the workshops, attendees learn about the basic skills used to build expert systems (e.g., knowledge acquisition - the systematic analysis and logical formalization of domain knowledge) and become familiar with the use of an expert system development tool. To enhance the practicality of the course, students were asked to select an actual problem from their workplace for which they themselves could provide the expertise. These ideas were then implemented during the course of the workshop both as a learning aid and as an initial prototype for possible further development. At the end of the workshop, the prototypes were demonstrated to management as examples of the types of real problems which can be readily solved with the technology.

2.2.4.2 Workshop Applications. Applications developed during the workshop were limited in scope due to the fact that time permitted only the development of demonstration versions. However, some ideas, such as contract performance evaluation, were selected by management for further prototype development. This development resulted in the CPEA system described earlier. Other good application areas for workshop exercises are classification, selection, and policy enforcement.

2.3 NEW TECHNOLOGY

Several activities supported the exploitation of new technology in the AI field. One effort was to develop a hypertext document handling tool. Other efforts in this area were an examination of example-based AI development shells, and a rule-based shell recently released by the National Aeronautics and Space Administration (NASA).

2.3.1 DocuView Hypertext Tool.

2.3.1.1 Purpose/Goals. The intended use of DocuView is for displaying general textual information on a computer screen. Hypertext expansion techniques are used for highlighting certain phrases within a document. Through selection of these phrases, those techniques allow a nonlinear traversal of the document.

2.3.1.2 Domain/Expertise. This software program is capable of being used wherever documents or general text materials need to be separated into pages for display purposes. The document developer, through various commands embedded in the text, has the flexibility to present the information in the most suitable manner for the particular domain being handled. The user, based on actual needs during presentation, has the control to dynamically alter the order in which the material is viewed. Thus, both the developer and user play a key role in the assimilation of hypertext information.

2.3.1.3 Requirements. This type of software tool is needed so that documents residing on the computer can be broken into logically defined pages for presentation as windows on a computer display screen. Documents must be stored in a form which allows modification by most text processors, yet must also be directly presentable by the document viewing tool.

2.3.1.4 Description. The DocuView tool is a software package consisting of a main program and numerous subprograms and functions written in a conventional computer language. The software is designed to present the contents of a document file, referred to as an object file, on a microcomputer display screen in user specified pages. Each page is defined to have its own window at a chosen location on the screen, and has a set of parameters which specify color, size, and other options. Pages are inserted into a text file by the addition of DocuView command lines. Other command lines are entered into the text to signify selected states or state changes. These commands make it possible for the DocuView user to work with varying document types and contents without experiencing conflicts between commands and the textual contents. For example, the command words and delimiters used in the text are changeable as needed by the user. As an example, the exclamation point character used to delimit highlighted phrases can be changed to some other character when conflicts in the document text arise.

2.3.1.5 Design/Development Characteristics. The most significant feature of DocuView is that it allows the document being analyzed to be broken up into pages for presentation on a computer display screen and that on these pages of text, chosen phrases can be highlighted for hypertext expansion into yet additional pages of commentary or description. The display of pages and hypertext expansion of selected phrases can be done recursively for page after page of textual information.

2.3.1.6 Benefits/Use. Information now stored on computer media or available in such form can be conveniently displayed on a computer screen. No significant changes to the original document are necessary. At the same time any text processing of the document is readily possible with conventional text editors. The real benefits though are to be realized with the display of only pertinent information and the resulting improvement in assimilating new information.

2.3.1.7 Development Status. Development has reached a stage where an initial version of the DocuView tool was distributed at one of the AI workshops and to other interested parties. Presently, comments received from formal and informal reviews are being incorporated into a new version. Possible improvements include increasing the types of parameters which are user-defined, providing a selective print function, and allowing easier use by such features as automatic sizing of text to fit a window.

2.3.2 Example-Based AI Development Tools.

Example-based shells use an inductive inference methodology. This technique accepts objects of a known class (i.e., the "examples") with a fixed collection of attributes. The attributes are distinguishing characteristics which determine which set of objects (class) a given object belongs to. After processing by an inductive algorithm, a decision tree with attributes is produced which may then be used to classify unknown objects. This methodology is well suited for classification, obviously, and diagnostic problems.

Example-based tools can be extremely easy to use since the development environment builds the rules automatically, given example situations as input. Although the tools are easy to use, some caution must be exercised to ensure that a potential problem domain is amenable to use of inductive techniques. Examples, of course, must exist, or the domain expert must be able to provide examples. Less obvious is that attributes which distinguish one set of objects from another must be defined. And, the examples used to build a system must be representative of the domain, and must cover all of the classes among which the system must distinguish. A good design methodology would also provide for ordering the attributes by the cost of obtaining the information. (An excellent paradigm of this last requirement is offered by a hypothetical medical diagnostic system. Attributes such as temperature, pulse rate, etc. would be used to identify a pathological condition, if at all possible, prior to requiring exploratory surgery.)

Example-based shells can provide other benefits as well. Some are good for discovering any underlying structure in low level data (i.e., they perform a "factor" or attribute analysis for the developer). Another useful feature of some shells is the ability to provide counterexamples where examples are are either too few or much too extensive (e.g., a medical diagnostic system which attempted to describe all the attributes of a well person).

To assess the potential of example-based tools an existing expert system, the Software Analyst's Assistant (SAA), was converted from a minicomputer to a microcomputer environment using the 1st-CLASS shell. The SAA was used in this capacity because the rules had been developed as examples, which made the conversion process itself a trivial undertaking, even though the SAA is a medium-sized system (approximately 500 rules). This exercise provided much insight into the specific features of the 1st-CLASS tool. (These will not be described in detail, other than to mention that the tool offers considerable flexibility, an extremely user-friendly interface, and a classification algorithm with a linear time function.) Most important is the capability to graphically display the decision tree built by the inductive algorithm. This logic tree can be examined to avoid creation of extraneous inferences, and conversely, to identify situations unaccounted for. (The conversion of the SAA resulted in the discovery of one instance of the latter case, although the impact of this oversight in SAA operation turned out to be insignificant.)

Used properly, with appropriately structured problems, an example-based shell can be a tremendously effective development tool. Microcomputer versions can adequately handle real size problem domains with performance comparable to, or better than, rule-based shells. But the most interesting feature (at least for a testing organization) is the ability to validate a system by visual and automatic examination of the logic tree.

2.3.3 NASA CLIPS.

The NASA C Language Integrated Production System (CLIPS) tool is a development and delivery expert system tool which provides a complete environment for the construction of rule-based expert systems. (Tools such as M.1 require the user to provide his/her own text editor.) Versions are available for a number of computer environments, including a microcomputer environment which is compatible with USAEPG resources. The CLIPS distribution package has a number of potentially useful and unique features. Source code and documentation are available at no cost to government agencies and their contractors (call the CLIPS Help Line at (713) 280-2233). The system is currently limited to forward chaining; but it has a powerful rule syntax, is portable, can be embedded within conventional procedural code, and can be extended with the addition of user-defined functions. In addition, CLIPS comes with a utility to aid in verification and validation of rules by providing cross referencing of fact relations, style checking, and semantic error checking. An Ada version of CLIPS (current implementation is in C) is also being developed.

Experience with the CLIPS environment has been too limited to provide an assessment of the full potential of this otherwise promising tool. A distribution copy was obtained, and the tool was introduced to attendees at a mini-workshop. Since the initial reaction of users has been favorable, after further experience with CLIPS has been gained, a more extensive workshop featuring this tool will be conducted.

2.4 TESTING AI ISSUES

This effort was undertaken as a survey of existing and proposed techniques for testing knowledge-based systems (KBS). The intent of the survey was to identify available techniques, assess their relationship to currently defined software quality factors, and make recommendations for their development and application.

Specific achievements this year have included: initial survey of existing and proposed techniques; construction of a data base reflecting technique to quality factor relationship; update of a previously initiated bibliography data base of materials related to such techniques; participation in organization and conduct of a workshop on validation and testing of KBS conducted at the 1989 International Joint Conference on Artificial Intelligence (IJCAI-89), to include acceptance of two papers for publication in the workshop proceedings.

The papers submitted covered an initial examination of the applicability of software reliability models investigated in previous methodology efforts to KBS and a summary of the initial testing technique survey results.

2.4.1 State of the Art.

In the past three to four years there has been a significant increase in efforts devoted to development of approaches and techniques for verification, validation, and testing (VV&T) of KBS. Three broad categories of effort have been identified to date. The first category consists of those projects aimed at defining the KBS life cycle and the role and form of VV&T appropriate within that context. The second category consists of projects aimed at developing high-level KBS system or subsystem assessments from some combination of objective, external, performance measures and subjective performance ratings. The last category consists of projects aimed at development of detailed and generally automated procedures for measurement of technical characteristics of KBS.

Projects in the first category have been only superficially examined. Since testing done by USAEPG occurs at specified points in an externally-specified life cycle, projects of this type have limited applicability. Their primary contribution is in identification of characteristics and criteria for KBS evaluation, and, in some cases, of applicable techniques.

Projects in the second category constitute the bulk of techniques immediately available for application. These techniques are drawn, with little or no alteration, from VV&T procedures for decision support and command and control systems. They require very little tailoring for application to KBS, and in many cases parallel techniques in use now at USAEPG. These techniques suffer from the drawback of being oriented towards evaluation of operational effectiveness, and provide little, if any, of the technical specificity required for developmental testing or reliability, availability, and maintainability (RAM) assessment.

Projects in the third category have the greatest potential for application to developmental and RAM-related testing. Most of them focus on static analysis of a KBS knowledge base, although a few do or soon will include consideration of inference engine characteristics as well. All of these projects suffer from three principle drawbacks. All are narrowly focused on a specific knowledge representation, in a manner analogous to the limitation of many static analysis tools for conventional software to a single language, or even a single dialect. All but two of the tools found thus far are research efforts and not generally available production quality tools. All but three of the tools exist independent of the development and maintenance environment, and hence require additional, ad hoc procedures to obtain the necessary source or other output for their application.

The allocation of each of the techniques examined to one or more software quality factors leads to the overall KBS VV&T state of the art rating given below:

Factor	Degree of Attention
Correctness	High
Reliability	High
Efficiency	Medium
Integrity	None
Usability	Low
Maintainability	Medium
Testability	Medium
Flexibility	Low
Portability	Low
Reusability	Low
Interoperability	Medium

The more detailed survey results are included in the copy of the workshop paper (reference 3).

2.4.2 Future Work.

The current effort of collecting technique documentation and entering the techniques in the project data base cross-referenced by software quality subfactors will continue. The final product is to be a collection of references indexed by subfactor which could aid a test officer in identifying those techniques applicable to a KBS embedded in an item submitted for test. The ultimate purpose of the collection would be the drafting a set of Test Operating Procedures (TOPs) for embedded KBS, although actual creation of the TOP will be dependent on further analysis and automation of selected procedures.

As indicated, in order to create TOPs for KBS testing it will be necessary to further analyze and define a selected set of techniques and to develop tools for their application. This will also require identification of KBS development tools employed in those projects likely to develop systems or prototypes to be submitted to USAEPG for test in order to allow development of implementing software for the selected techniques.

Logical candidates for initial implementation include the tests incorporated in Lockheed's Expert Validation Assistant (EVA), the matrix techniques of Aerospace Corporation, and the complexity metric proposed by Structured Systems and Software. These are identified and references are provided in the referenced workshop paper.

2.5 AVAILABILITY OF TOOLS

Most of the tools developed during the investigation are available to other Government agencies or their contractors. For current information on the availability of a tool, contact:

Bob Harder
Chief, USAEPG AI Office
AUTOVON 821-8183/8187

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SECTION 3. APPENDIXES

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APPENDIX A. METHODOLOGY INVESTIGATION PROPOSAL

28 August 1987

METHODOLOGY INVESTIGATION PROPOSAL

1. TITLE. AI Test Officer Support Tool

2. INSTALLATION OR FIELD OPERATING ACTIVITY. US Army Electronic Proving Ground, Fort Huachuca, Arizona 85613-7110.

3. PRINCIPAL INVESTIGATOR. Mr. Robert Harder, Software and Interoperability Division, STEEP-ET-S, AUTOVON 821-8187.

4. BACKGROUND. Test design and planning for modern C^3I systems require familiarity with a number of test operating procedures (TOPs) as well as detailed knowledge of specific test tool capabilities. A wide variety of tests must be designed, planned, and scheduled in order to efficiently conduct testing. Interrelationships among test groups and tools, common data requirements and data reduction and analysis requirements, lead time to prepare instrumentation, and required availability of the test item must be well understood in order to efficiently conduct tests within allocated time constraints.

USAEPG has explored the feasibility of an automated system to support the test officer. Using Independent Laboratory In-house Research (ILIR) funds, a prototype system was developed using AI technology. The prototype addressed tests performed by the Simulation and Interference Branch primarily, but could be expanded for other test areas.

5. PROBLEM. Testing C^3I systems involves designing and planning tasks which are becoming increasingly complex. Advances in technology such as microprocessor design, distributed real-time architectures, artificial intelligence, and electro-optics are appearing in new C^3I developments. While this sophisticated technology offers benefits to the developer, it is becoming a considerable burden to the tester. Test officers are required to identify appropriate test methods and associated instrumentation and data acquisition requirements for each emerging technological area. This requires a level of expertise which is rarely found in any one individual. Besides being distributed among individuals, and therefore less available, this hard-earned expertise is frequently lost to the organization because of personnel reassignment or attrition.

6. OBJECTIVE. To improve test methodology by providing the test officer with an automated support tool.

7. MISSION AREA(S) SUPPORTED. All DA mission areas for systems containing embedded computer resources (ECR) are supported. The "Big 5" program categories (C^3, RSTA, etc.) are accommodated by the nonsystem-specific nature of the methodology.

8. PROCEDURES.

a. Summary. The investigation will draw upon previous ILIR efforts by expanding the level of detail and the scope. The result will be an enhanced tool supporting the test officer in specific domains such as electromagnetic compatibility, software testing, and general test mechanisms. Other domain categories will be explored as time permits.

b. Detailed Approach. The USAEPG will:

(1) Extract and codify knowledge from cognizant individuals in fields including electromagnetic and software testing.

(2) Examine other test areas to identify tests performed, responsible branches, test instrumentation capabilities, and characteristic test requirements. Commonality among these various factors will be identified to form a framework which will accommodate all test functions, instrumentation, and resources. Following implementation of the generalized framework, specific test areas (knowledge domains) will be analyzed in depth and incorporated into the tool.

c. Final Product(s).

(1) An AI test officer support tool with enhanced capability--more "smarts" in the existing area of coverage, and additional test areas covered.

(2) Requirements and recommendations for automation of test design and planning functions.

d. Coordination. Extensive coordination with the various test groups of the USAEPG is an inherent characteristic of the investigation. To the extent that test areas covered overlap the areas of interest of other I/FOAs, coordination will be accomplished through existing mechanisms such as the TECOM Software Technical Committee (TSOTEC).

e. Environmental Impact Statement. Execution of this task will not have an adverse impact on the quality of the environment.

f. Health Hazard Statement. Execution of this task will not involve health hazards to personnel.

9. JUSTIFICATION/IMPACT

a. Association with Mission. This investigation directly supports USAEPG's mission relative to test and evaluation. Providing test officers with automated support tools will improve the efficiency and effectiveness of testing.

b. Association with Methodology/Instrumentation Program. This project supports thrusts of the TECOM Methodology Program to improve the quality of testing as well as test process.

c. Present Capability, Limitations, Improvement, and Impact on Testing if not Approved.

(1) Present Capability. TOPs and guidelines, such as the USAEPG Test Officers Handbook, provide static information on test methods and checklists for test planning purposes.

(2) Limitations. Current guidelines often do not provide the level of detail required for optimized application of scarce test resources. Also, the information is static; status of test instrumentation, competition for resources among different test items, and the impact of not performing some test (or lack of test material such as certain documentation) is poorly handled unless the test officer's experience has included similar situations.

(3) Improvement. Using AI techniques to develop a support tool can provide the test officer sufficiently detailed and flexible guidelines. Beside being adaptable to the needs of a specific test item and current with respect to test instrumentation availability, the proposed approach would be sensitive to data requirements and be able to anticipate the impact if tests are not performed. Supported over time, such a tool could accumulate expertise which is presently distributed and too frequently lost.

(4) Impact on Testing if not Approved. The expertise required of test officers is rapidly expanding in scope as innovative technologies are increasingly employed by developers. The corresponding increase in complexity of test methods and instrumentation demands a commensurate improvement in support tools if test resources are to be effectively and efficiently used. Also, without permanent storage and readily available access to "lessons learned", the corporate memory of an activity suffers each time an experienced individual leaves the organization.

10. DOLLAR SAVINGS. No directly supportable dollar savings can be projected at this time. Indirect benefits include improving the quality of testing and evaluation leading to improved quality of fielded systems. Equally difficult to quantify is the retention, concentration, and increased availability of expertise, which is potentially a significant amount.

11. RESOURCES.

a. Financial.

	Dollars (Thousands) FY88		Dollars (Thousands) FY89	
	In-House	Out-of-House	In-House	Out-of-House
Personnel Compensation	10.0		12.0	
Travel	3.5		4.0	
Contractual Support		84.5		42.5
Materials & Supplies	2.0		1.5	
Subtotals	15.5	84.5	17.5	42.5
FY Totals	100.0		60.0	

b. Explanation of Cost Categories.

(1) Personnel Compensation. This cost represents compensation chargeable to the investigation for using technical or other civilian personnel assigned to the investigation.

(2) Travel. This represents costs incurred while visiting government and industry facilities.

(3) Contractual Support. Performance of the investigation will be accomplished with resources provided under an existing support contract.

c. Obligation Plan (FY89).

	FQ 1	2	3	4	Total
Obligation Rate (Thousands)	45.0	5.0	5.0	5.0	60.0

d. Man-Hours Required.

In-House:

Contract:

12. ASSOCIATION WITH TOP PROGRAM. This investigation will not directly produce a TOP. However, various TOPs may require review and revision based on the findings.

FOR THE COMMANDER:

(signed)
ROBERT E. REINER
Chief, Modernization and
Advanced Concepts Division

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APPENDIX B. REFERENCES

1. Methodology Investigation for Software Technology for Adaptable, Reliable Systems (STARS), Final Report: Test Methodology with Artificial Intelligence, Harder, et al., U.S. Army Electronic Proving Ground, Fort Huachuca, Arizona, March 1987.

2. Methodology Investigation Final Report, AI Test Officer Support Tool, Volume I, U.S. Army Electronic Proving Ground, Fort Huachuca, Arizona, March 1989.

3. N. Sizemore, Test Technology for Knowledge Based Systems: A Survey. Proceedings of IJCAI-89 Workshop on Verification, Validation, and Testing of KBS, August 1989 [in preparation].

Note: Domain-specific references are available upon request.

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APPENDIX C. ACRONYMS AND ABBREVIATIONS

ADP............ Automated Data Processing
AI............. Artificial Intelligence
AMC............ United States Army Materiel Command
AR............. Army Regulation
ASCII.......... American Standard Code for Information Interchange
ASL............ Atmospheric Sciences Laboratory
BUD2........... Budget Spreadsheet Analysis Aid Expert System
C^3............ Command, Control, and Communications
C^3I........... Command, Control, Communications and Intelligence
CLIPS.......... C Language Integrated Production System
CPEA........... Contract Performance Evaluation - Advisor Expert System
DA............. Department of the Army
DoD............ Department of Defense
DTP............ Detailed Test Plan
ECR............ Embedded Computer Resources
ES^2............ Expert System Selector
EVA............ Environmental Impact Assessment Expert System
EVA............ Expert Validation Assistant (Lockheed AI test tool)
EXSYS.......... Expert System Development Package
I/FOA.......... Installation Field Operating Activity
IJCAI-89....... 1989 International Joint Conference on AI
ILIR........... Independent Laboratory Inhouse Research
KBS............ Knowledge Based Systems
MET............ Meteorological Expert System
MS DOS......... Microsoft Disk Operating System
NASA........... National Aeronautics and Space Administration
PT............. Physical Training
RAM............ Reliability, Availability, and Maintainability
REC............ Record of Environmental Consideration
RSTA........... Reconnaissance, Surveillance, and Target Acquisition
SAA............ Software Analyst's Assistant Expert System
SBIR........... Small Business Innovative Research
SEC............ Security Expert System
S&I............ Software and Interoperability Division (USAEPG)
SOP............ Standard Operating Procedure
STARS.......... Software Technology for Adaptable, Reliable Systems
TECOM.......... United States Army Test and Evaluation Command
TOP............ Test Operating Procedure
TPD............ Test Plan Drafter
TSOTEC......... TECOM Software Technical Committee
TTES........... Tape Test Expert System
UAV............ Unmanned Aerial Vehicle
USAEPG......... United States Army Electronic Proving Ground
VV&T........... Verification, Validation, and Testing

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APPENDIX D. PREVIOUS APPLICATIONS

This section contains descriptions of the major prototype expert system applications previously reported. They are included here to provide a summary of prior results without having to reference other documents.

1. Test Plan Drafter.

1.1 Purpose/Goals.

The near-term goal of the TPD is to automate the current manual assembly of boilerplate for an initial draft of a detailed test plan (DTP). This is a time-consuming effort consisting of much cut-and-paste work from old test plans, but little real intellectual effort. It is intended to result in a strawman version for distribution to specific subtest domain experts for further editing.

A longer term goal of the effort is to create a prototype knowledge infrastructure, i.e., a structure for centralized maintenance of both specific information pertaining to a given test and general information needed in test planning.

1.2 Domain/Expertise.

The initial knowledge acquisition for TPD involved determining the structure and composition of a DTP. This is specified in part by applicable regulation. Further detail was provided through review of local policy and interviews with test officers and with USAEPG's Technical Publications Division personnel responsible for preparing and publishing test plans.

Subsequent efforts involved acquisition of previously drafted boilerplates for specific subtests and review of Army, AMC, TECOM, and USAEPG publications to refine the knowledge of test plan composition and of the overall test and evaluation process in the Army. This latter knowledge, in addition to aiding in understanding the test planning process, is essential to realizing the desired training benefits from use of the intended tool.

1.3 Requirements.

The general requirements laid on all the application efforts selected were that they be of wide utility and also aid in training of personnel. Requirements specific to TPD were that it reduce the manual and telephonic work required to reach the strawman stage for a DTP, that it provide information on test plan structure and component descriptions, and that it assist the novice test officer in understanding the test and evaluation process. Requirements added during the prototype development were that it assist in draft DTP preparation and in the mechanics of the DTP review process.

A requirement of the TPD infrastructure was that it be maintainable in a form accessible to a broad range of offices. For this reason, the tool selected to create and maintain these components should be one that is widely available and understood by personnel not necessarily involved in or familiar with expert system or AI development.

1.4 Description. The current TPD prototype performs four functions:

a. It provides a simple mechanism for entering and maintaining standard information pertinent to a specific test.

b. It creates a partial strawman DTP from the information entered.

c. It provides background information on the test and evaluation process in general, as well as on specific components of a test plan.

d. It provides a mechanism for preparing a draft DTP and limited assistance in review thereof.

1.5 Design/Development Characteristics.

The primary development environment selected for TPD was dBASE III. This environment allows attainment of the infrastructure goals without having to retrofit the infrastructure at a later time. The AI-related tools used are HYPE, from Knowledge Garden, Inc., and EXSYS (Expert System Development Package), obtained from California Intelligence, Inc. HYPE allows use of the hypertext paradigm for help and explanation functions. EXSYS allows development of expert system components. One further tool, DOCUCOMP, from Advanced Software, Inc., provides a document comparison facility for identifying changes made to a standard subtest to tailor it for a specific system. This is the limited assistance provided in draft DTP preparation and in the mechanics of the DTP review process (section 1.3).

The initial TPD prototype consists entirely of the dBASE III and HYPE files and software dealing with creation and maintenance of test plan information, and associated help and explanation files. The dBASE III application software drives the application, invoking HYPE and DOCUCOMP where appropriate.

1.6 Benefits/Use.

TPD is designed to be used primarily by a lead test officer for a specific system, to assist in preparing a strawman DTP. Another potential user is the manager evaluating a proposed test outline for a potential customer.

The current TPD prototype is installed in the Command and Control Division of the Command, Control, and Communications (C^3) Test Directorate. It has been used in production of several strawman DTPs, and the current users have made several suggestions for improvement.

The most obvious benefit to be gained from the TPD is time. Current users and others to whom TPD has been demonstrated indicate that the current manual method of strawman draft plan composition can take from two days to two weeks. The TPD output is available within 15 to 30 minutes. While the resulting product is not complete, it accounts for perhaps as much as 30 to 50 percent of the content of such a strawman. Some increase in this percentage will accrue from growth in the archive of standard subtests, while some must await implementation of further planned functions.

Less obvious is the training and standardization benefit. The hypertext provided with TPD makes available to the novice much information previously available only by laborious searching through assorted regulations and pamphlets. It also indicates sources for further information. Moreover, while in the past the differing backgrounds and levels of experience among test officers have sometimes led to irregularities in DTP and subtest format, more widespread use of a single tool offers the promise of improved adherence to TECOM and local guidance with less administrative review and rewriting effort. This will allow test officers, test engineers, and managers to devote more of their time and effort to substantive test issues.

1.7 Development Status. TPD prototype functionality is roughly 70 percent complete. Addition of the expert system components for subtest recommendations and coordination requirements will bring the system to a level that will permit initial formal evaluation of its utility. This will require making the tool more widely available to test officers, which will in turn require additional copies of supporting software.

1.8 Future.

Given that the TPD proves worthy of continued development, three major lines of development are foreseen. The first is expansion and refinement of the knowledge-based portion of the system, i.e., the hypertext and expert system components. These offer considerable potential for expansion into expert test planning areas, such as costing and scheduling, as well as tutorial and advisory components for test officer training.

The second area involves the conventional, infrastructure component. It is important here to note only that this effort has created a skeletal infrastructure in conventional code to investigate the maintenance and integration problems that might arise.

The third line of development involves support tool integration. The use of a conventional basis for this tool, and development of a standard shell for passing the information contained in a test-specific data base to an expert system component, constitutes an example of one integration approach. Further refinement of this mechanism and comparison with others, is essential to allow integration of the support tools into a single package for use by the test officer.

2. Environmental Impact Assessment Expert System.

2.1 Purpose/Goals. The purpose of EVA is to assist the test officer and environmental personnel in collecting accurate environmental information during the early planning phases of test activities, and in making appropriate recommendations based on characteristics of the proposed activities. Specific goals of the system were to:

a. Identify tests with minimal or no environmental impacts, and streamline the documentation process.

b. Identify possible environmental impacts and the resources that could be affected (e.g., water, wildlife, cultural, historical).

c. Improve the quality, detail, and timeliness of information provided to environmental personnel during the initial stages of a test project.

d. Incorporate environmental information into the initial decision-making stages of a project.

e. Guide activity proponents through the environmental assessment process, and list points of contact for action items and regulatory requirements.

2.2 Domain/Expertise.

The domain of EVA covers that area of knowledge required to identify potential environmental impacts, recognize categorical exclusions from the rules for certain damaging activities, and perform a preliminary screening to determine the probable environmental documentation requirements. This expertise resides with the USAEPG environmental quality coordinator and environmental specialists attached to the post garrison. These experts in turn consult specialists in more narrow domains when necessary.

As EVA evolved through various prototype stages, additional information from documented sources was incorporated into the design. This information consisted more of quantitative impact factors, rather than intuitive knowledge about the domains. The inferences about this data were supplied by the human domain experts.

At the end of prototype development the following sources had been used in generating the data bases and rules of EVA:

a. U.S. Army Corps of Engineers
   (1) Construction Engineering Research Laboratory reports
   (2) Archaeologist

b. U.S. Department of Agriculture, Soil Conservation Service

c. U.S. Army Environmental Hygiene Agency

d. Fort Huachuca
   (1) Forester
   (2) Wildlife Biologist
   (3) Fish Biologist
   (4) Environmental Specialist

Much credit is due the post environmental specialist for identifying sources of information and eliciting knowledge from subdomain experts. This effort exceeded the scope of the normal participation of an expert, and aided tremendously in knowledge acquisition activities.

2.3 Requirements.

USAEPG is required to conform to federal and state environmental regulations as well as Army and DoD policy in these matters. Every proponent of an exercise or test at Fort Huachuca is required to address the environmental issues associated with the activity. USAEPG test officers have the additional responsibility for assessing potential environmental impacts for any activity resulting from a test directive, regardless of the nature of the testing.

The result of the preliminary impact assessment is a record of environmental consideration (REC). The REC documents the consideration of environmental impacts; possible outcomes are that the activity is adequately covered by existing documentation, qualifies for an established categorical exclusion or other exemption, or requires an environmental assessment. Environmental assessments subsequently result in a "finding of no significant impact" or indicate that an extensive environmental impact statement is required.

Most of USAEPG's activities are conducted at locations specifically designated and documented for that type of activity, or are conducted entirely within an enclosed facility, as such computer simulation and modeling. Thus, the major requirement of a preliminary environmental screening is to discriminate as early as possible between typical situations requiring little further documentation, and those requiring a significant environmental impact study.

2.4 Description. The EVA elicits information about a proposed activity from the test officer, and reaches a preliminary conclusion on the actions required. It then generates a report containing action items, and summary and detail characteristics of the activity, with corresponding environmental impacts. Activities which have already been documented or qualify for a categorical exclusion are quickly identified (i.e., a minimum of user input is required), and the necessary REC report is generated. For activities where the potential environmental impact is greater, the user may elect to examine the environmental resources most affected and, if possible, modify characteristics of the proposed activity to minimize the impact and associated documentation. In any event, information from the report is used by the environmental quality coordinator in completing the environmental requirements.

2.5 Design/Development Characteristics.

The EVA system consists of an expert system which provides the user interface, contains the rules used to make decisions, generates reports, and interfaces with other tools for additional capabilities. These other tools supply such functions as access to data bases and graphic display of map information. Other components include supporting information such as help, system parameter, map, point-of-contact, and report specification files. The expert system shell, EXSYS, allows a means to interface with the other tools and files so efficiently that the user is generally unaware of the individual components. To further isolate the user from having to contend with directory structures and operating system commands, a set of command files was created to simplify the installation and operation of EVA. The user merely enters one command to run the system and display and print the results.

The main expert component of EVA contains about 120 IF-THEN rules in the knowledge base. When processed by the EXSYS inference engine, the rules serve to collect the necessary information to reach the final conclusion on the environmental impacts of the proposed activity. Forward chaining, a technique which determines how the rules are processed, also allows some control over the sequence in which events take place. Thus, the user can be presented with queries in the same relative order, even though the knowledge base and supporting data bases may have changed from previous versions.

Although all of the rules may apply to a given scenario, only those which rely upon unknown information will request the user to enter needed data. Besides background information such as project number and description, which are always requested, firing (processing) of the rules may trigger queries on up to 150 numerical or textual variables, and up to 35 multiple-choice questions. For example, if the activity will include aircraft, then information is requested on the number of aircraft, number of flight hours, and time of day and altitude of the flights. Because only essential information is requested, an EVA session can last anywhere from 5 to 45 minutes.

Part of the development philosophy was to minimize the amount of knowledge to be included in the rules about a specific installation. Information on the location of sensitive resources, period of sensitivity if not constant throughout the year, and qualitative damage factors associated with particular activities, were placed in ten data bases. These data bases were designed to be readily understood and modified by the domain experts without first having to obtain knowledge engineering skills. Likewise, user help screens, point-of-contact information, etc., which contained installation-specific material, were kept in separate files. This approach may provide a ready means of porting the system to other installations, but was chosen primarily to reduce development and maintenance costs. Information contained in the various data bases and files could have easily been encoded into rules, and some expert development packages provide the capability to do just that when fed tabular data. The problem with a pure expert system solution, with all of the knowledge embedded in rules, concerns the size of the resultant rule base. It was estimated that to incorporate the knowledge in the data bases alone into rules would add another three to four hundred rules. Further development and maintenance of such an unwieldy knowledge base would have significantly impeded progress, with no known advantages.

2.6 Benefits/Use.

EVA offers benefits to the test officer, environmental quality coordinator, and program manager. Test officers are given the opportunity to compare environmental effects of different activities at various locations and times. With little prior knowledge of environmental concerns, the test officer using EVA can quickly gain an appreciation of the relative impact of various activities through the questions asked, the associated help text, and the outcome of the proposed scenarios. Less experienced test officers also benefit from the action items and notes related to the proposed activity; e.g., contacting the fire marshal and filing a fire plan if incendiary devices are used, or coordinating tree and brush removal with the post forester. These serve as reminders even for seasoned test officers, and both inexperienced and experienced users of the system benefit from reduced paperwork and coordination.

EVA does not make complicated environmental decisions, write environmental assessments or environmental impact statements, or replace environmental personnel. In fact, environmental quality coordinators themselves can use EVA to refine the work initiated by test officers, or as a method of automating and documenting activities in a standard fashion. Tests with minimal environmental impact are identified with a savings of paperwork and time. Even for large activities not fully handled by EVA, the quality, consistency, and detail of information presented to environmental personnel is greatly improved. Without EVA, many preliminary meetings are required between the test officer and environmental quality coordinator, merely to establish what information is needed, and then the data is rarely available in an organized format.

Sponsors of testing activities may gain the most from the use of EVA, albeit somewhat indirectly. Because extensive environmental documentation requirements can cause lengthy and expensive delays, it is important to identify potential impacts as early as possible, and develop alternative test scenarios which are more environmentally benign. Advance warning of potentially expensive activities, such as disposal of hazardous materials (e.g., expended batteries), may, if given in time, allow implementation of more cost-effective solutions.

2.7 Development Status. EVA is currently installed on several microcomputer systems at Fort Huachuca; about 20 test officers have been formally trained in its use. Presently the system is in an evaluation phase, where feedback is being obtained concerning its use in test operations.

2.8 Future. A number of ideas for further development of EVA have been proposed. During its construction, the development team identified a number of desirable features which could not be implemented because of time constraints. Other valuable ideas emerged from the test officer training sessions. However, the actual usefulness and benefits to be realized must be determined from the results of the ongoing evaluation. Some of the more significant limitations and improvements to be considered in future efforts are the following:

a. Some of the knowledge in EVA is in a preliminary state, having been added to determine the feasibility and desirability of certain features (e.g., a component to address hazardous materials). Those features deemed desirable should be expanded, along with the rest of the system, into a fully operational form.

b. The potential for porting the system to other installations should be explored further. This would require an initial analysis of the requirements of other installations, to see if enough commonality exists in the knowledge domains to make this approach feasible. Such an investigation might also shed some light on the commonality of other requirements, such as test resource management and safety.

c. The prototype system has the limitation that only one map area can be entered as the location of activity. Although areas may be arbitrarily defined as large or small as desired, a cumbersome situation occurs with activities consisting of 100 or more sites with minimal impact at each location. Even smaller activities may be handled better if multiple locations, or if unrestricted boundaries are allowed.

d. A feature which would allow saving all of the input information, to be used later to examine the impact of different test scenarios, is desirable. Such a capability was partially implemented, but had to be disabled because of a software discrepancy in the expert system tool. Along these same lines, many users expressed the desire to be able to modify an entry that had just been made. Both seem to be necessary features for practical use in an operational environment.

e. Most of the data bases of EVA are indexed by location. Geographic information also plays an important part in many other functions at Fort Huachuca. A solution to many of these needs for information associated with geographic position would be a geographic information system. This is also a requirement of many other proposed test tools. While implementation and maintenance of such a system is well beyond the scope of this investigation, the potential usefulness is great enough to warrant development by other means.

f. The actual users of EVA range from inexperienced test officers to qualified environmental personnel. Because of the disparity in experience, a system tailored to a given skill level will be somewhat frustrating for users of a different level. Experienced users quickly tire of a system oriented toward the novice, while inexperienced users may find a system written for the expert to be much too difficult. A possible solution to this dilemma was discovered during the EVA development, but too late to fully evaluate. Basically, this approach, if implemented, would call for multiple levels of rules, help, and queries. A "don't understand" option is provided on higher level queries. When invoked by the novice, this option fires lower level rules which elicit a number of simpler details from the user. These details are then formulated by the lower level rules into facts which satisfy the original, "difficult" query. Such an approach is best implemented on mature knowledge bases because of the growth in size and commensurate decline in maintainability. For a system with a diverse user base, further examination of this technique may prove useful.

3. <u>Meteorological Expert System</u>.

3.1 <u>Purpose/Goals</u>. The Meteorological Expert System (MET) began originally as a manual paper checklist for test officers to use in preparing for upcoming tests at Fort Huachuca. It is designed to emphasize the need for meteorological data in planning and reporting tests within USAEPG. MET also indicates that various meteorological measurements and advisories are available from the Atmospheric Sciences Laboratory (ASL) weather station at Fort Huachuca, and from other sites located on the Fort Huachuca ranges.

3.2 <u>Domain/Expertise</u>. This expert system deals with the knowledge encompassing meteorological measurements and/or those weather events which affect test operations on the ground or in the atmosphere where testing will take place. Generally these measurements or observations are provided by ASL.

3.3 <u>Requirements</u>. From the standpoint of the test officer, the need for an expert system on weather is that it can educate and inform the test officer about meteorological data requirements and available resources for a test. The need for such data comes primarily when the test will be conducted outdoors. The expert system will make clear that the officer will need to have weather predictions before the test in order to plan for conditions such as cold or heat, rain or snow, and wind or lightning. Weather advisories and weather alerts from ASL can warn the test officer in the field of impending sudden weather changes that could endanger personnel and equipment.

3.4 Description.

The MET system educates the test officer as to possible weather-related needs, and informs the officer on how to obtain needed measurements to prepare for the test, how to run the test more effectively, and how to obtain weather station support in reporting the test outcome.

Measurements and predictions of temperature, dew point, rain, snow, thunderstorm activity, and winds in the lower atmosphere, may be needed. Predictions may be needed as to meteorological conditions such as sunspot activity and atmospheric index of refraction. MET informs the test officer whether, during on-site test activities, weather advisories and reports of selected meteorological values are available and may be needed. Also the ASL weather station's ability to support test reporting is covered.

The result of using the MET system is that the test officer can produce better test data by being prepared with needed meteorological data, both in measurements that directly supply parameters needed in the calibration of equipment such as radar, and in supplying measurements for the test, as well as weather advisories that assist in day-to-day running of test operations.

Without MET, the test officer must know to inform ASL of test requirements far enough in advance to prepare them to supply information needed for the test. ASL may need to prepare ahead of time to be able to make measurements during the test, and will need to know what data are needed for the test report. ASL can supply reports of the meteorological conditions that existed during testing.

3.5 Design/Development Characteristics.

The MET system is composed of a series of questions which are presented to a test officer from within the EXSYS shell. The questions asked in this prototype version of MET determine, for example, whether lasers will be used in the atmosphere, whether any radar or unmanned aerial vehicles (UAVs) will be used, whether personnel and/or equipment will be in the field, and whether heavy rain or snow will be a problem. From such factors, MET can then advise that meteorological measurements will be needed to support these activities. For example:

a. Aerosol density in the atmosphere or optical scintillation measurements may be needed for a test involving lasers.

b. Meteorological data used in radar calibration may be needed for a test using or testing radar.

c. Measurements of upper air winds and turbulence could be needed for a test using UAVs.

d. Weather advisories would be wise to have during test activities.

MET automates the original weather/meteorological checklist into a system in which the questions are presented on the computer monitor for decision, help is provided by way of a computer-stored text file for each question, and the answers are stored in computer memory until the sessions end, when a report including all input answers is produced. The report is displayed on the computer monitor and printed on the line printer, under operator control.

3.6 Benefits/Use. The benefit of using the MET system is that the test officer becomes better informed about available support from the ASL weather station, and learns what weather conditions require special preparation. The test officer can then more likely plan the test so as to produce a more accurate result, and will be able to write a more correct and informative report. This all adds up to savings in time and money.

3.7 Development Status. MET has been developed only to the initial evaluation stage. In this prototype version, MET has been placed on 10 microcomputers in the USAEPG and ASL offices at Fort Huachuca, so as to be available for use by all test officers. Statistics on system usage and comments on deficiencies or possible improvements have not yet been collected.

3.8 Future. After evaluation, the MET prototype will be modified to eliminate any discrepancies found, and to enhance the system's capabilities to better serve test officer needs. Questions will be improved to clarify their meaning. The MET help file will be changed, as needed, to make explanations more useful to the user. The sequence of questions presented to each test officer will be determined by previous answers to prevent redundancies.

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